# Final Report

## Brine Streams

## Potential Impacts and Opportunities for the Water Industry

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Prepared for

Smart Water Fund

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# Table of Contents



## Tables

# Abbreviations

| Abbreviation | Description |
|---|---|
| CRCs | Cooperative Research Centres |
| CSIRO | Australian Commonwealth Scientific and Research Organisation |
| DSE | Department of Sustainability and Environment |
| EPA | Environment Protection Authority Victoria |
| GWMWater | Grampians-Wimmera-Mallee Water |
| MCA | Multi-Criteria Analysis |
| R&D | Research and Development |
| RO | Reverse Osmosis |
| SWF | Smart Water Fund |
| TBL | Triple Bottom Line |
| TDS | Total Dissolved Solids |
| WAIV ponds | Wind-aided intensified evaporation ponds |
| ZLD | Zero Liquid Discharge |

# Glossary of Disposal Methods

| | |
|---|---|
| Deep Well Injection | This option is site specific because it requires the right geological conditions. These conditions are typically characterised by a deep confined aquifer with adequate pressure in the aquifers above it to ensure cross-contamination does not occur. However, geologic conditions may allow for deep wells to have a depth of a few hundred feet or several thousand feet. |
| Discharge to Land / Rapid Infiltration | Rapid infiltration over a land surface is a means to dispose of concentrate quickly by percolation through a soil at high loading rates. It is not typically a viable alternative for disposal of brine or concentrate from most membrane treatment facilities. This technique allows for large volumes of water (100mm to as much as 2 metres) to be used to recharge groundwater, surface water, and/or being available in bores for extraction and use for other purposes. |
| Discharge to Sewer | By discharging the brine stream to sewer, the brine stream and product water reunite in the sewer collection system for treatment at the wastewater treatment plant. |
| Discharge to Surface Water | Discharge to surface water is the simplest disposal option and the most commonly used option due to its low costs. Surface waters include the ocean, rivers, lagoons and other bodes of water. This method involves pumping brine from the point of production to a nearby body of water. |
| Evaporation Ponds | If there is sufficient land, heat and wind, then evaporation ponds can be effective for disposing concentrate. This method involves discharging brine to ponds constructed with appropriate liners and depth to allow for containment of brine streams and pan evaporation. |
| Wind-aided Intensified Evaporation (WAIV) Ponds | WAIV ponds offer the potential to increase the rate of evaporation through the use of upright structures supporting wetted surfaces that allow wind to aid in the evaporation of liquid. These ponds may reduce the overall land footprint by 40 percent when compared with traditional evaporation ponds. |
| Zero liquid Discharge (ZLD) | ZLD is a technology that typically involves the use of mechanical evaporation equipment to concentrate a brine stream and subsequently crystallises it so that it can be transported to a licensed landfill site for disposal. |

# Introduction

Due to the prevailing drought conditions, Water Corporation's throughout Victoria are turning to desalination technologies to meet demands. For inland Water Corporation's, the management of the desalination brine stream is a significant challenge.

The aim of this project was to provide Water Corporations in Victoria with a better understanding of management options for concentrate/brine wastewater streams generated.

Existing methods for managing concentrate/brine wastewaters were evaluated, as well as beneficial and non-traditional uses that may have applicability in the geographical setting of inland Victoria.

In order to evaluate management of concentrate/brine in Victoria, URS worked with three Water Corporations (Wannon Water, Central Highlands Water and GWMWater) to quantify the quality and quantity of brine streams which they will need to manage in the future. The main issues which they need to address to manage the brine streams were identified, including the socio-economic impact of not providing this additional water to the community.

A comprehensive review was also conducted, to identify innovative solutions to the overall management of brine streams. These solutions were evaluated using a Triple Bottom Line (TBL) criterion to allow comparison of different projects and to enable the identification of projects which have the potential for success in Victoria. The intent of which is to guide the Water Corporations' for the future direction of research and development (R&D) of brine streams.

The key steps involved in the project were as follows:

- Project Planning – detailing the project scope, communication milestones and overall project management.
- Workshop and Issues Paper – identify and quantify potential brine streams for each location identified by Water Corporations; present findings at a Water Corporation Workshop; develop an Issues Paper identifying common issues which would impact on the TBL.
- Review and Evaluate Technologies – conduct a literature review on brine stream management worldwide, undertake interviews with Universities and Cooperative Research Centres (CRCs) on current and future R&D for the management of brine streams, review each of the management practices using a TBL.
- Industry Forum – present the findings from the project and promote discussion between Victorian Water Corporations and industry.

This report presents a summary of the key steps and findings of the project. For further details on these key steps, the relevant report (i.e. the Issues Paper, 9$^{th}$ February 2009 and Triple Bottom Line Assessment, 24$^{th}$ April 2009) should be consulted.

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# Issues Paper and Industry Forum

## 2.1 Summary of the Issues Paper

An Issues Paper was prepared to identify common issues which would impact on the TBL. Drafts of the paper were reviewed by the three Water Corporations prior to the final document being submitted to SWF on 9th February 2009. A summary of the Issues Paper is presented below.

### *Identifying the Issues*

The purpose of the Issues Paper was to present the major issues which were identified from information provided by Water Corporations. Each of the Water Corporations was asked to provide details on the water quality and water demand into the future.

This information was used to model the quantity and quality of reject streams produced by Reverse Osmosis (RO) treatment. The following aims were used when establishing the model:

- Provide a reliable, palatable, potable water supply with the use of RO.
- Improve the option for recycled water use with the removal of high TDS using RO.

The outcome of the model enabled the identification of:

- Estimated volume (kL per year) of brine;
- Estimated concentration (as total dissolved solids) of brine stream;
- Estimated mass (annual load) of salt contained in brine stream; and
- Estimated increased demand in raw water requirements for communities requiring supplemental potable water supply.

### *Why is Desalination Needed?*

On-going drought, trade waste discharges, and poor quality water supply has driven Water Corporations to investigate the use of desalination to mitigate these drivers. The major drivers for desalinisation are:

- Drought – reduction in rainfall is resulting in low surface water volumes. Water supplies have been augmented using brackish groundwater.
- Trade Waste Discharge Quality – a discharge from a waste stream (industrial or water treatment plant) is increasing the TDS of wastewater.
- Poor Water Quality – the source water is of poor quality due to high TDS concentrations in the water supply.

### *Brine Management Options*

Conventional methods typically used to manage brine streams include:

- Discharge to sewer;
- Deep well injection;
- Evaporation ponds;
- Discharge to surface water; and
- Rapid infiltration (shallow subsurface disposal).

## 2 Issues Paper and Industry Forum

As part of the workshop held on 21st October 2008, conventional methods for managing brine streams were presented to each of the Water Corporations. Advantages and disadvantages published in the literature were presented and discussed by workshop participants, in the context of each town participating in this project. Discussions included the feasibility of each management option by Water Corporations, to provide an initial indication of the viability of a particular option for a particular town/region.

Table 2-1 provides a summary of the outcomes from the workshop and the initial assessment for each method and its viability.

**Table 2-1 Workshop Summary of Conventional Disposal Methods for each Location**

| Management Option | Clunes | Avoca | Maryborough | Edenhope | Nhill | Pt Fairy Water | Pt Fairy Recycled Water | Heywood | Mortlake |
|---|---|---|---|---|---|---|---|---|---|
| Discharge to Sewer | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ |
| Deep Well Injection | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ |
| Evaporation Ponds | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ |
| Surface Water Discharge | ✗ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ |
| Rapid Infiltration | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |

### *Beneficial and Non-traditional Uses*

Beneficial and non-traditional uses are another means of prolonging the use of brine streams prior to ultimately disposing or managing the salt. In general, these uses include:

- Oil/Gas Well Field Injection to aid recovery of oil and gas resources;
- Solar Ponds to collect and store solar energy;
- Land Application and Irrigation for landscape or selected crops;
- Zero Liquid Discharge for production of dry salts and recovery of high purity distillate water;
- Aquaculture for sea and estuarine fish species;
- Wetlands Creation and Restoration;
- Constructed Wetland Treatment; and
- Others
  - Stormwater and Wastewater Blending;
  - Feedstock for Sodium Hypochlorite Generation;
  - Dust Control and De-Icing;
  - Recreational Use; and
  - Transport of minerals

## 2.2 Industry Forum

On 20th May 2009 an Industry Forum was held by URS with representatives from each of the Water Corporations, as well as staff from EPA Victoria and CSIRO. The purpose of the forum was to present the key findings from the project and promote discussion/exchange of ideas and issues between Water Corporations and EPA.

The presentations given at the forum were as follows:

- Project overview;
- Overview of the Issues Paper;
- Current research and technologies;
- Review and management practices using TBL;
- Presentation on current research (CSIRO);
- EPA presentation (EPA); and
- Where to from here? (Question & Answer session)

Discussions were held throughout the day and questions were raised on various aspects of the project. There was a particular focus by the Water Corporations on the future policy direction of EPA and other regulatory departments, with regard to approvals and licensing requirements as they relate to the brine disposal options presented.

Other points raised and discussed included the following:

- EPA is aware of the growing trend to desalinate brackish/saline water for higher value use and that there would be a growing need to find other way to manage/dispose of the resulting brine.
- The discussions by workshop participants recognised deep well injection as an attractive alternative based upon salinity management in soils and the surface environment.
- EPA is currently reviewing policies and guidelines to allow alternative methods of management of brines; however at this time their policy stance for options such as deep well injection is not yet clear.
- EPA highlighted the issue that deep well injection schemes will need a high level of investigation, assessment and review. This would typically be carried out in the context of EPA's works approval and licensing system, and would require detailed characterisation of aquifers, details of surrounding uses, robust modelling and monitoring programs, and submissions would be considered on a case-by-case basis. This process however, is largely untested and submissions to EPA would need to demonstrate that the proposed disposal option would have no impact on the beneficial uses of groundwater or other receiving environments.
- EPA indicated that for traditional and non-traditional brine management options, other regulatory departments, such as water authorities and the Department of Sustainability and Environment (DSE) would also need to be consulted as part of the approval process. EPA would likely require involvement of the audit system.
- Evaporation ponds were identified by workshop participants as the most obvious brine management option. However the question was posed as to whether this option is always the best way to dispose of brine streams. It was argued that the future development of green field sites could make this option economically unfeasible due to the costs of purchasing large areas of land.

## 2 Issues Paper and Industry Forum

- There was consensus among those present at the forum on the importance of planning. It was pointed out that, due to the effects of climate change, 'emergency' situations in regard to water scarcity could become the norm and therefore the use of groundwater to augment water supplies needs to become part of the overall solution to Victoria's water shortage. To this regard, numerical modelling would be recommended to support any application. This applies particularly to the design and optimum operation of evaporation ponds, to predict the number and size of ponds required (based on estimated population growth and future demand), to eliminate situations in which unplanned ponds are required to be constructed, increasing capital and operational costs.
- Consideration of aquaculture as a possible 'disposal' option was also raised at the forum, as well as the importance of trying to harness excess heat/energy from other industries when siting desalination plants. Recovering salts as by-products was also raised by CSIRO, however this is not considered to be an economically viable option due to the chemical characteristics of brine. Most brine streams from potable water treatment plants will consist primarily of sodium and chloride which are abundant in the environment.

# Overview of Management Practices Evaluated

Feedback from the industry workshop conducted in October 2008 with representatives from the three Water Corporations indicated that there were four main management options relevant to the study areas, namely evaporation ponds, deep well injection, Zero Liquid Discharge (ZLD) and Wind-aided intensive evaporation (WAIV) ponds. Table 3-1 below presents a summary evaluation of each of these options.

**Table 3-1 Evaluation of the Brine Stream Management Options: Overview**

| Disposal option | Advantages | Disadvantages |
|---|---|---|
| Evaporation ponds | • Considered to be the most likely management option, given technical feasibility.<br>• Relatively simple technology,<br>• Can be used to manage a wide range of concentrations.<br>• Particularly well-suited to arid climates. | • Potential habitat and ecological risks (e.g. potentially to some waterbird species) must be considered.<br>• Potential seepage to groundwater if the pond liner fails; monitoring is required.<br>• Potential for surface leakage could adversely affect nearby soil quality and vegetation.<br>• Land requirements may cause the removal of vegetation in green fields. |
| Deep well injection | • Does not require treatment of the brine and concentrate prior to disposal.<br>• Potentially low environmental risk, if aquifer of similar salinity found.<br>• Causes minimal (if any) adverse consequences for air and surface environments (soil and surface water). | • Costs can be exacerbated if multiple injection and monitoring wells are required.<br>• Requires careful well construction to prevent brine impact on intermediate aquifers.<br>• Regulatory and approval requirements are untested and require further development.<br>• Approval likely to be conditioned on a relatively onerous monitoring regime. |
| Zero Liquid Discharge (ZLD) | • Brine streams processed faster than evaporation ponds.<br>• Solid waste volume significantly less than other management options<br>• High quality water vapour by-product that can be used for other purposes. | • Requires significant energy input.<br>• Costs are relatively high.<br>• High energy requirements.<br>• Potential for significant volumes of Greenhouse Gas emissions. |

# 3 Overview of Management Practices Evaluated

| Disposal option | Advantages | Disadvantages |
| --- | --- | --- |
| Wind-aided intensified evaporation (WAIV) ponds | • Reduced overall land footprint compared to traditional evaporation ponds.<br>• Size of evaporation ponds can be as much as 40% smaller than traditional evaporation ponds. | • Potential habitat and ecological risks (e.g. potentially to some waterbird species) must be considered.<br>• Potential seepage to groundwater if the pond liner fails; monitoring is required.<br>• Potential for surface leakage could adversely affect nearby soil quality and vegetation.<br>• Pumping costs tend to make operating costs for this option higher than traditional evaporation ponds.<br>• Potential for salt drift may require mitigation. |

# TBL Criteria and Assessment

Based on feedback from the Issues Paper and the workshop, results from the interviews with researchers and the results from the literature review, the most appropriate evaluation methodology was considered to be Multi-Criteria Analysis (MCA). MCA is an assessment tool that allows monetary and non-monetary data associated with various management options to be considered by assigning scores and weights to priced and non-priced data. The weights express the importance of each TBL effect to the decision-maker or stakeholders.

The hypothetical nature of the options to be assessed meant that a detailed quantitative MCA was not possible, so a qualitative MCA was undertaken, with the purpose of identifying those areas where site-specific factors will be important, or where further research is required. This approach does not rely on quantitative scores and weights (as would be the case under a traditional MCA), rather it utilises a set of colour-coding to compare the options in much the same way that the Water Corporations assessed options for securing water supplies in their Water Supply and Demand Strategies.

The ranking descriptions and colours used to rank the options are contained in Table 4-1 (for financial criteria) and Table 4-2 (for environmental and socio-economic criteria). They were developed in consultation with URS technical experts.

**Table 4-1 Rank Descriptions (Financial)**

| Rank description | Rank |
|---|---|
| Expensive (total cost > $2,000/ML) | |
| Moderately expensive (total cost:$1,501 - $2,000/ML) | |
| Relatively inexpensive (total cost: $1,000 - $1,500/ML) | |

**Table 4-2 Rank Descriptions (Environmental and Socio-economic)**

| Rank description | Rank |
|---|---|
| Always problematic with complex mitigation measures | |
| Occasionally problematic with moderate mitigation measures | |
| Rarely problematic with simple mitigation measures | |

Using this ranking system, each of the management options was assessed. The results of which are presented in Table 4-3 below.

## 4 TBL Criteria and Assessment

**Table 4-3 Option Assessment Summary**

| Criteria | Evaporation ponds | Deep well injection | Zero liquid discharge (ZLD) | Wind-aided intensive evaporation |
|---|---|---|---|---|
| **Financial** | | | | |
| Total cost ($/ML, based on 3.79 ML/day) | | | High operating costs owing to energy requirements | Moderate operating costs owing to capital and land requirements |
| **Environmental** | | | | |
| Water receptors (e.g. aquatic species and habitat) | | Ecological risks are low, unless it fails and discharges to surface water | | |
| Air receptors (e.g. birds, insects and air quality) | Some concentrations may contain constituents that pose a hazard to avian receptors. | | | Some concentrations may contain constituents that pose a hazard to avian receptors. |
| Land receptors (e.g plants, animals and habitat) | | | | |
| GHG emissions | | Owing to energy requirements | Owing to energy requirements | |
| Noise | | | Because mechanical equipment is used | |
| | | | | |
| **Socio-economic** | | | | |
| Health (potential effect on human health) | | Potential for migration to potable water supplies. | | Possibility of localised noxious odours |
| Visual amenity (facility's effect on human amenity) | Relatively large area of land required | | Infrastructure can be obtrusive | Reduced area of land required, but infrastructure may be more obtrusive |
| Public acceptance (likelhood of public opposition). | | Because of risk to groundwater | Because of energy consumption | Potential for salt draft |
| Regulatory requirements/approval | | Unknown regulatory environment | But may be more problematic because of high GHG emissions | Marginally more assessment required for approval than evap. Ponds |

## 4 TBL Criteria and Assessment

Based on the qualitative MCA undertaken for this project, it appears that it is not possible to draw general conclusions about the 'best' management option. Each of the options has advantages and disadvantages, the specific nature of these factors need to be assessed on a case-by-case basis.

Broadly speaking, it appears that traditional evaporation ponds are the least problematic. ZLD is potentially the most problematic owing to its high energy requirements, which has flow on implications for the cost and potentially the public acceptance of this option. Deep well injection, being a relatively untested technology in this context, does not have an accompanying regulatory and approvals process, which may undermine public acceptance of this option. WAIV ponds have potential to create a number of adverse human and environmental effects, relative to traditional evaporation ponds.

The extent to which these factors are problematic or require further investigation will depend on the site specific characteristics and details of a given management option. Although mitigation measures are available for all of the areas of concern, these will generally involve higher costs, which may reduce the overall viability of the option, depending on the Water Corporations' abilities to recover these costs.

# Recommendations for Future Research

It is recommended that the next stage in the investigation of brine disposal be the selection of a specific site, development of specific site parameters and the application of the TBL to that site. This will provide valuable information on the relative costs and benefits of each disposal.

# Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of the Smart Water Fund and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 9 November 2007.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between May 2009 and February 2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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